SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Kaori Fujimura, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan, Kiyotaka Otsuji, a citizen of Japan residing at Kamakura-shi, Kanagawa-ken, Japan, Yuichi Fujino, a citizen of Japan residing at Kiyose-shi, Tokyo-to, Japan, Sakuichi Ohtsuka, a citizen of Japan residing at Yokohama-shi, Kanagawa-ken, Japan, Koji Ogawa, a citizen of Japan residing at Yokohama-shi, Kanagawa-ken, Japan, Hitomi Sato, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan and Harumi Kawashima, a citizen of Japan residing at Yokosuka-shi, Kanagawa-ken, Japan have invented certain new and useful improvements in

TOMOGRAPHIC IMAGE READING METHOD, AUTOMATIC ALIGNMENT METHOD, APPARATUS AND COMPUTER READABLE MEDIUM

of which the following is a specification:-

ℓ L179105586

TITLE OF THE INVENTION
TOMOGRAPHIC IMAGE READING METHOD,
AUTOMATIC ALIGNMENT METHOD, APPARATUS AND COMPUTER
READABLE MEDIUM

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BACKGROUND OF THE INVENTION
1. Field of the Invention
The present invention generally relates to
a slice image automatic alignment method and
10 apparatus used for comparing a tomographic image of
an object such as a computerized tomography (CT)
image with another tomographic image of the same
object which are taken at different times. The
tomographic image is generated by CT, MRI(magnetic
15 resonance imaging) or the like.
2. Description of the Related Art
In a medical field, comparison between a
present image and a previous image provides a clue
for determining whether a shade in an image is a
20 tumor or not and whether it is malignant or not. As
one method for the comparison of images, when a
doctor finds a suspicious shade in a diagnostic
image, the doctor may search for comparison images
showing a position which corresponds to that of the
25 diagnostic image so as to compare the images. The
technique for supporting the doctor to compare
images is disclosed in, for example, "METHOD FOR
AUTOMATICALLY COMPARING SLICED IMAGES OF CHEST
THREE-DIMENSIONAL TOMOGRAPHIC IMAGES", Japanese
30 laid-open patent application No.10-53172 and
"COMPARATIVE INTERPRETATION OF RADIOGRAM BY CT IMAGE
FOR MASS EXAMINATION", Ukai et al., JAMIT
Frontier '98, pp140-145.
The above-mentioned technique in "METHOD
35 FOR AUTOMATICALLY COMPARING SLICED IMAGES OF CHEST
THREE-DIMENSIONAL TOMOGRAPHIC IMAGES" is a method
for comparing each slice of the diagnostic images

with comparison image slices for finding a
corresponding comparison image. Although the method
can cope with changes of body condition and movement
of the lower part of a lung for breathing, there is

5   a problem that the process takes a long time since
the slice needs to be compared with comparison image
slices one by one. According to the above-mentioned
conventional technique "COMPARATIVE INTERPRETATION
OF RADIOGRAM BY CT IMAGE FOR MASS EXAMINATION",

10 sections of a lung field are classified, then,
features such as a lung field area, a heart area,
and a descending aorta are extracted and automatic
image comparison is performed on the basis of the
location of the features. However, there is a

15 problem that it takes a long time to extract the
features.

Accordingly, when a doctor carries out
diagnosis by comparing chest tomographic images, it
takes time to see a comparison image which

20 corresponds to the diagnostic image, or it is
necessary to compare present images with previous
images. In this case, since all images need to be
compared, normal images as well as suspicious images
need to be compared. Therefore, it takes time to

25 perform often useless comparisons.

SUMMARY OF THE INVENTION

It is an object of the present invention
to provide a tomographic image reading method, an

30 automatic alignment method, the apparatus and the
computer readable medium in which slice images of
the same body position can be obtained automatically
at high speed from two sequences of chest
tomographic images of the same person such that the

35 slice images can be presented to a doctor in a short
time.

The above object of the present invention

is achieved by a tomographic image reading method for extracting a comparison image corresponding to a diagnostic image and displaying the images, the diagnostic image being a slice image which is one of

5   first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at a time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial

10   direction and body axis being in the Z axial direction, the method comprising the steps of:

inputting the first tomographic images and the second tomographic images;

generating a first projection image from

15   the first tomographic images and a second projection image from the second tomographic images;

measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same

20   area using a template, the template being generated from the first projection image such that the template includes an area in which a specific object image exists;

correcting the slice position according to

25   the shift amount between the first projection image and the second projection image; and

displaying the diagnostic image and the comparison image at a corrected slice position to a monitor.

30   According to the above-mentioned method for aligning positions of diagnostic images and comparison images so as to extract a comparison image corresponding to a diagnostic image, since the projection image is used, the shift can be detected

35   quickly, and a diagnostic image and a comparison image in which slice position shift is corrected can be displayed on a monitor in a short time.

The above object of the present invention
is also achieved by an image alignment method for
extracting a comparison image corresponding to a
diagnostic image and displaying the images, the
diagnostic image being a slice image which is one of
first tomographic images, the comparison image being
a slice image which is one of second tomographic
images which are taken at a time different from the
time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial
direction and body axis being in the Z axial
direction, the method comprising the steps of:

inputting the first tomographic images and
the second tomographic images;

aligning resolutions of the first
tomographic images and the second tomographic images
by scaling one or both of the tomographic images
when the resolutions of the first tomographic images
and the second tomographic images are different;

generating a first projection image from
the first tomographic images and a second projection
image from the second tomographic images;

measuring shift amount between the first
projection image and the second projection image by
searching the second projection image for the same
area using a template by performing pattern matching
while shifting the template by an interval, the
template being generated from the first projection
image such that the template includes an area in
which a specific object image exists;

correcting the slice position according to
the shift amount between the first projection image
and the second projection image; and

displaying the diagnostic image and the
comparison image at a corrected slice position on a
monitor.

The image alignment method may include an

adjusting step of adjusting positions of the
diagnostic image and the comparison image which are
displayed;

5   wherein a MIDI signal constructing method
is used for the adjusting step, the MIDI signal
constructing method comprising the steps of:

              providing n different MIDI channels or
control numbers or combinations of them for a signal
x which has $128 \times n$ stages in which n is a positive
10   integer;

              assuming the MIDI channels or the control
numbers or the combinations as $p = 1, 2, \cdots n$;

              dividing the signal x into 128 parts
$W(1)(1 ; 0 \leq 1 \leq 127)$ in ascending order and assigning p
15   which is equal to $r+1$ $(r ; 0 \leq r < n)$ to the signal x
which is equal to $1 \times n + r$;

              constructing and sending a MIDI control
change message in which a control value is 1 by
using a MIDI channel or control number corresponding
20   to p.

              According to the above method, automatic
position alignment can be performed at high speed
and the result can be displayed. In addition, the
displayed image can be adjusted precisely. That is,
25   by using the MIDI signal constructing method for the
terminal operation, the operation can be performed
effectively.

              The above object of the present invention
is also achieved by a slice image automatic
30   alignment method for extracting a comparison image
corresponding to a diagnostic image, the diagnostic
image being a slice image which is one of first
tomographic images, the comparison image being a
slice image which is one of second tomographic
35   images which are taken at a time different from the
time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial

direction and body axis being in the Z axial
direction, the method comprising the steps of:

inputting the first tomographic images and
the second tomographic images;

5   aligning resolutions of the first
tomographic images and the second tomographic images
by scaling one or both of the tomographic images
when the resolutions of the first tomographic images
and the second tomographic images are different;

10   generating a first projection image from
the first tomographic images and a second projection
image from the second tomographic images;

measuring shift amount between the first
projection image and the second projection image by
15   searching the second projection image for the same
area using a template by performing pattern matching
while shifting the template by an interval, the
template being generated from the first projection
image such that the template includes an area in
20   which a specific object image exists; and

correcting the slice position according to
the shift amount between the first projection image
and the second projection image.

The step of generating projection images
25   may include the step of:

generating the projection image comprising
pixel values obtained by adding pixel values (for
example, CT values, gray level, density value or the
like) of the tomographic images in the X or Y axial
30   direction or in any other direction.

According to the above mentioned method,
the shift can be detected quickly. By correcting
the shift in the comparison images, automatic
aligning for slice images can be performed quickly.

35   The step of generating projection images
may include the step of:

generating a two dimensional image

sequence comprising pixel values obtained by adding pixel values of the tomographic images in the X or Y axial direction or in any other direction; and

5
generating the projection image by interpolating the two dimensional image sequence.

According to the method, the position of slice images can be aligned accurately.

In the above-mentioned method, the template may be an area of 25% to 50% from the top

10
end of the first projection image in the Z axial direction. Accordingly, pattern matching can be performed effectively. Especially, when the object part is lung, the effect is remarkable.

The above object of the present invention

15
is also achieved by a slice image automatic alignment method for extracting a comparison image corresponding to a diagnostic image, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a

20
slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial

25
direction, the method comprising the steps of:

inputting the first tomographic images and the second tomographic images;

aligning resolutions of the first tomographic images and the second tomographic images

30
by scaling one or both of the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

finding a reference position in the Y axial direction for each of the first tomographic

35
images and the second tomographic images and correcting shift in the Y axial direction on the basis of the reference position;

generating a first projection image in the X axial direction from the first tomographic images and generating a second projection image in the X axial direction from the second tomographic images;

5   measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same area as a template by performing pattern matching while shifting the template by an interval, the

10   template being generated from the first projection image such that the template includes an area in which a specific object image exists; and

      correcting the slice position according to the shift amount between the first projection image

15   and the second projection image.

      The above object of the present invention is also achieved by a slice image automatic alignment method for extracting a comparison image corresponding to a diagnostic image, the diagnostic

20   image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken,

25   body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the method comprising the steps of:

      inputting the first tomographic images and the second tomographic images;

30   aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of the tomographic images when the resolutions of the first tomographic images and the second tomographic images are different;

35   generating a first projection image in the X axial direction from the first tomographic images and generating a second projection image in the X

axial direction from the second tomographic images;

finding a reference position in the Y axial direction from each of the first projection image and the second projection image and correcting

5   shift in the Y axial direction on the basis of the reference position;

measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same

10   area using a template by performing pattern matching while shifting the template by an interval, the template being generated from the first projection image such that the template includes an area in which a specific object image exists; and

15   correcting the slice position according to the shift amount between the first projection image and the second projection image.

In the above-mentioned method, the step of generating projection images may include the step

20   of:

generating a two dimensional image sequence comprising pixel values obtained by adding pixel values of the tomographic images in the X axial direction; and

25   generating the projection image by interpolating the two dimensional image sequence.

The step of finding the reference position and correcting shift may include the steps of:

extracting a bed area as the reference

30   position from the first tomographic image and the second tomographic image or the first projection image and the second projection image;

correcting shift in the Y axial direction on the basis of the bed surface, the Y axial

35   direction being perpendicular to the bed surface.

In addition, the step of finding the reference position and correcting shift may include

the steps of:

finding a body part which contacts the bed as the reference position from the first tomographic image and the second tomographic image or the first
5   projection image and the second projection image;

correcting shift in the Y axial direction on the basis of the part, the Y axial direction being perpendicular to the part.

Further, the step of finding the reference
10   position and correcting shift may include the steps of:

finding a backbone part as the reference position from the first tomographic image and the second tomographic image or the first projection
15   image and the second projection image;

correcting shift in the Y axial direction on the basis of the backbone part, the Y axial direction being perpendicular to the backbone part.

According to the above mentioned methods,
20   the shift can be detected quickly. By correcting the shift in the comparison images, automatic aligning of slice images can be performed quickly. In addition, since shift correcting is performed by using the bed position or a distinctive part of the
25   body as a reference, search area can be decreased. Therefore, calculation amount can be decreased.

In the above mentioned invention, the step of generating projection images may include the step of generating the projection image in which weight
30   is assigned to a specific observation object by setting a window level and a window width.

According to the method, better matching results for a specific part such as bone or lung tissue and speedy processing can be realized.
35   Further, the step of generating projection images may includes the step of generating the projection image in which only a part including a

distinctive part is projected.

According to the method, the area of the projection image or the search area can be narrowed. Therefore, better matching results for a specific part and speedy processing can be realized.

Further, the step of measuring the shift amount may include the steps of:

generating a plurality of templates;

performing template matching on the second projection image by using a plurality of templates; and

measuring shift amount between the first projection image and the second projection image from a plurality of reference points.

According to the method, shift correction of the slice position becomes more accurate and the better matching result can be obtained. Especially, when comparing the lower part of lung, shift due to breathing can be corrected.

The above object of the present invention is also achieved by a tomographic image reading apparatus for extracting a comparison image corresponding to a diagnostic image and displaying the images, the diagnostic image being a slice image which is one of first tomographic images, the comparison image being a slice image which is one of second tomographic images which are taken at the time different from the time when the first tomographic images are taken, body section being a slice plane in the X-Y axial direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first tomographic images and the second tomographic images;

projection image generation means for generating a first projection image from the first

tomographic images and a second projection image
from the second tomographic images;

5   template generation means for generating a
template from the first projection image such that
the template includes an area in which a specific
object image exists;

matching means for measuring shift amount
between the first projection image and the second
projection image by searching the second projection
10   image for the same area as the template;

slice position correcting means for
correcting the slice position according to the shift
amount between the first projection image and the
second projection image; and

15   displaying means for displaying the
diagnostic image and the comparison image at a
corrected slice position on a monitor.

According to the invention, since the
projection image is used, the shift can be detected
20   quickly and a diagnostic image and a comparison
image in which slice position shift is corrected can
be displayed on a monitor in a short time.

The above object of the present invention
is also achieved by an image alignment apparatus for
25   extracting a comparison image corresponding to a
diagnostic image and displaying the images, the
diagnostic image being a slice image which is one of
first tomographic images, the comparison image being
a slice image which is one of second tomographic
30   images which are taken at a time different from the
time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial
direction and body axis being in the Z axial
direction, the apparatus comprising:

35   inputting means for inputting the first
tomographic images and the second tomographic
images;

resolution aligning means for aligning
resolutions of the first tomographic images and the
second tomographic images by scaling one or both of
the tomographic images when the resolutions of the
5   first tomographic images and the second tomographic
images are different;

projection image generation means for
generating a first projection image from the first
tomographic images and a second projection image
10   from the second tomographic images;

template generation means for generating a
template from the first projection image such that
the template includes an area in which a specific
object image exists;

15   matching means for measuring shift amount
between the first projection image and the second
projection image by searching the second projection
image for the same area as the template by
performing pattern matching while shifting the
20   template by an interval;

slice position correcting means for
correcting the slice position according to the shift
amount between the first projection image and the
second projection image; and

25   displaying means for displaying the
diagnostic image and the comparison image at a
corrected slice position on a monitor.

The above object of the present invention
is also achieved by a slice image automatic
30   alignment apparatus for extracting a comparison
image corresponding to a diagnostic image, the
diagnostic image being a slice image which is one of
first tomographic images, the comparison image being
a slice image which is one of second tomographic
35   images which are taken at the time different from
the time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial

direction and body axis being in the Z axial direction, the apparatus comprising:

inputting means for inputting the first tomographic images and the second tomographic

5 images;

resolution aligning means for aligning resolutions of the first tomographic images and the second tomographic images by scaling one or both of the tomographic images when the resolutions of the

10 first tomographic images and the second tomographic images are different;

projection image generation means for generating a first projection image from the first tomographic images and a second projection image

15 from the second tomographic images;

template generation means for generating a template from the first projection image such that the template includes an area in which a specific object image exists;

20 matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same area as the template by performing pattern matching while shifting the

25 template by an interval; and

slice position correcting means for correcting the slice position according to the shift amount between the first projection image and the second projection image.

30 According to the above mentioned apparatus, the shift can be detected quickly. By correcting the shift in the comparison images, automatic aligning for slice images can be performed quickly.

The above object of the present invention

35 is also achieved by a slice image automatic alignment apparatus for extracting a comparison image corresponding to a diagnostic image, the

diagnostic image being a slice image which is one of
first tomographic images, the comparison image being
a slice image which is one of second tomographic
images which are taken at a time different from the
5   time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial
direction and body axis being in the Z axial
direction, the apparatus comprising:

inputting means for inputting the first
10 tomographic images and the second tomographic
images;

resolution aligning means for aligning
resolutions of the first tomographic images and the
second tomographic images by scaling one or both of
15 the tomographic images when the resolutions of the
first tomographic images and the second tomographic
images are different;

reference position recognition means for
finding a reference position in the Y axial
20 direction from each of the first tomographic image
and the second tomographic image;

shift correcting means for correcting
shift in the Y axial direction on the basis of the
reference position;

25   projection image generation means for
generating a first projection image of the X axial
direction from the first tomographic images and
generating a second projection image of the X axial
direction from the second tomographic images;

30   template generation means for generating a
template from the first projection image such that
the template includes an area in which a specific
object image exists;

matching means for measuring shift amount
35 between the first projection image and the second
projection image by searching the second projection
image for the same area as the template by

performing pattern matching while shifting the
template by an interval; and

slice position correcting means for
correcting the slice position according to the shift
5   amount between the first projection image and the
second projection image.

The above object of the present invention
is also achieved by a slice image automatic
alignment apparatus for extracting a comparison
10   image corresponding to a diagnostic image, the
diagnostic image being a slice image which is one of
first tomographic images, the comparison image being
a slice image which is one of second tomographic
images which are taken at a time different from the
15   time when the first tomographic images are taken,
body section being a slice plane in the X-Y axial
direction and body axis being in the Z axial
direction, the apparatus comprising:

inputting means for inputting the first
20   tomographic images and the second tomographic
images;

resolution aligning means for aligning
resolutions of the first tomographic images and the
second tomographic images by scaling one or both of
25   the tomographic images when the resolutions of the
first tomographic images and the second tomographic
images are different;

projection image generation means for
generating a first projection image of the X axial
30   direction from the first tomographic images and
generating a second projection image of the X axial
direction from the second tomographic images;

reference position recognition means for
finding a reference position in the Y axial
35   direction from each of the first projection image
and the second projection image;

shift correcting means for correcting

shift in the Y axial direction on the basis of the reference position;

template generation means for generating a template from the first projection image such that the template includes an area in which a specific object image exists;

matching means for measuring shift amount between the first projection image and the second projection image by searching the second projection image for the same area as the template by performing pattern matching while shifting the template by an interval; and

slice position correcting means for correcting the slice position according to the shift amount between the first projection image and the second projection image.

According to the above mentioned apparatuses, the shift can be detected quickly. By correcting the shift in the comparison images, automatic aligning for slice images can be performed quickly. In addition, since shift correcting is performed by using the bed position or a distinctive part of the body as a reference, search area can be narrowed. Therefore, calculation amount can be decreased.

In addition, the present invention is a computer readable medium storing program for causing a computer to perform processes according to the method of the present invention.

According to the computer readable medium, a program of the present invention can be stored or distributed. In addition, it becomes easy to realize the present invention by using a computer.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from

the following detailed description when read in
conjunction with the accompanying drawings, in
which:

Figs.1A and 1B are diagrams for explaining
5   X, Y, and Z axes in a chest CT image according to an
embodiment of the present invention;

Fig.2A is a diagram for explaining
projection directions according to a first
embodiment of the present invention;

10   Figs.2B and 2C are diagrams showing
examples of a projection image;

Fig.3 is a schematic diagram showing a
configuration example of a chest CT image alignment
apparatus according to the first embodiment;

15   Fig.4 is a block diagram showing another
configuration example of the chest CT image
alignment apparatus according to the first
embodiment;

Fig.5 is a flowchart showing a procedure
20   for measuring position shift and displaying the
diagnostic image and the comparison image of the
same position according to the first embodiment;

Fig.6 is a flowchart showing generation
process of the projection image of the diagnostic
25   images according to the first embodiment;

Fig.7 is a flowchart showing generation
process of the projection image of the comparison
images according to the first embodiment;

Fig.8 is a diagram for explaining template
30   pattern matching method according to the first
embodiment;

Fig.9A shows the direction of projection
according to a second embodiment of the present
invention;

35   Fig.9B is a projection image in the X
axial direction according to the second embodiment;

Fig.10 is a schematic diagram showing a

configuration example of a chest CT image alignment
apparatus according to the second embodiment;

Fig.11 is a block diagram showing another
configuration example of the chest CT image
5   alignment apparatus according to the second
embodiment;

Fig.12 is a flowchart showing a procedure
for measuring position shift and displaying the
diagnostic image and the comparison image of the
10   same position according to the second embodiment;

Fig.13A is a diagram for explaining a
reference point for correcting shift in the Y axial
direction according to the second embodiment;

Fig.13B is a diagram for explaining a
15   reference point for correcting shift in the Y axial
direction according to a third embodiment;

Fig.14 is a diagram for explaining
template pattern matching method according to the
second and third embodiments;

20   Fig.15 is a block diagram showing a
configuration example of the chest CT image
alignment apparatus according to the third
embodiment;

Fig.16 is a flowchart showing a procedure
25   for measuring position shift and displaying the
diagnostic image and the comparison image of the
same position according to the third embodiment;

Fig.17 is a block diagram showing a
hardware configuration of a computer;

30   Fig.18 is a diagram for explaining signal
assignment;

Fig.19 shows relations between a slider
position, a channel and a value;

Fig.20 is a diagram for explaining a
35   method for assigning channels, control numbers and
the combinations.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following embodiments of the present invention will be described with reference to figures.

5   In the following embodiments, concerning chest X ray CT images for lung cancer screening, present images are compared with previous images.
(first embodiment)

The first embodiment of the present

10   invention will be described.

Figs.1A and 1B are diagrams for explaining X, Y, and Z axes in the chest CT image. Assume that the X-Y axial direction forms a slice plane of a tomographic of body such as chest or the like as

15   shown in Fig.1B, and that the Z axial direction is a moving direction of a patient bed as shown in Fig.1A. The chest X ray CT images for lung cancer screening are taken by a helical scan CT shown in Fig.1A and information of slice thickness in the Z axial

20   direction is included in a slice image of chest tomographic of X-Y axial direction.   The number of images to be taken is from 25 to 30 for one person.

Figs.2B and 2C are diagrams showing examples of a projection image.   Fig.2A shows the

25   direction of projection.   Fig.2B is a projection image in which all CT values, which are gray levels, are added in the X axial direction as shown in Fig.2A.   Fig.2C is a projection image in which all CT values, which are gray levels, are added in the Y

30   axial direction shown in Fig.2A.   In this embodiment, the projection image of the Y axial direction as an example will be used.

Fig.3 is a schematic diagram showing a configuration example of a chest CT image alignment

35   apparatus according to the embodiment.

A reference number 1 shows a file storing chest tomographic images (diagnostic images) taken

this year and a reference number 2 shows a file storing chest tomographic images (diagnostic images) taken last year. A reference number 3 shows a projection image generated by the file 1 and a

5 reference number 4 shows a projection image generated by the file 2. In the sequence of CT images stored in the files 1, 2, position shift between past images and present images is occurred due to differences of subject positions or by

10 deformation of lung due to breathing. A reference number 5 shows a computer system for automatically aligning position of slice images of the file 1 with position of slice images of the file 2 and displaying slice images at a position obtained by

15 the alignment.

Fig.4 is a block diagram showing another configuration example of the chest CT image alignment apparatus according to the embodiment.

The chest CT image alignment apparatus

20 includes a terminal apparatus 11 to which a tomographic image reading apparatus 12, a mouse 13, a keyboard 14, and a monitor 15 are connected. The terminal apparatus 11 includes an apparatus control part 111 and a slice image automatic alignment

25 function part 112 for tomographic images. The slice image automatic alignment function part 112 for tomographic images includes a slice image automatic alignment function and control part 112-1 for tomographic images, a diagnostic image sequence file

30 112-10, a comparison image sequence file 112-11 and a correction image sequence file 112-12 of comparison images. An operating input part 112-2, a tomographic image external input part 112-3, a resolution matching processing part 112-4, a

35 projection image generation processing part 112-5, a template generation processing part 112-6, a matching processing part 112-7, a slice position

correction processing part 112-8, and a display
processing part 112-9 are connected to the slice
image automatic alignment function and control part
112-1 for tomographic images. The operating input

5   part 112-2 performs data input by connecting the
mouse 13 and the keyboard 14. The tomographic image
external input part 112-3 inputs tomographic images
from the tomographic image reading apparatus 12.
The display processing part 112-9 displays

10   diagnostic images and comparison images to the
monitor 15.

The tomographic image external input part
112-3 writes data to the diagnostic image sequence
file 112-10. The resolution matching processing

15   part 112-4 reads data from the diagnostic image
sequence file 112-10 and the comparison image
sequence file 112-10. In addition, the resolution
matching processing part 112-4 writes to the
correction image sequence file 112-12 of comparison

20   images. The projection image generation processing
part 112-5 and the display processing part 112-9
read data from the diagnostic image sequence file
112-10 and the correction image sequence file 112-12
of comparison images.

25   A MIDI device 16 such as a pedal, a dial,
and a slider is connected to the operating input
part 112-2. Using the MIDI device, it is possible
to adjust the position of the Z axial direction of
tomographic images displayed on the monitor minutely.

30   The detailed description of the MIDI device will be
given later.

Fig.5 is a flowchart showing a procedure
for measuring position shift and displaying the
diagnostic image and the comparison image at the

35   same position in order to support image comparison
by software in the computer shown in Fig.3 or by
each processing part of the image alignment

apparatus shown in Fig.4. In the flowchart,
parenthesized processing parts, which are included
in the image alignment apparatus in Fig.4,
corresponding to the following procedure are shown.
5   The flowchart will be described.

In Fig.5, diagnostic image sequence $f_z(x,$
y) which is a slice image sequence and comparison
image sequence $g_z(x, y)$ which is also a slice image
sequence are input in step 1 (tomographic image
10   external input part 112-3).

In step 2, when resolution of the
diagnostic images and resolution of the comparison
images are different, resolution matching processing
is performed for correcting the comparison images
15   such that the resolution of the comparison images
agree with that of the diagnostic images by scaling
using three-dimensional interoperation or leaner
interpolation (resolution matching processing part
112-4).

20   Next, in step 3, projection images for
each images of the diagnostic images and the
comparison images are generated (projection image
generation processing part 112-5).

Fig.6 is a flowchart showing generation
25   process of the projection image of the diagnostic
images.

First, three-dimensional diagnostic images
(slice image sequence) which comprise pixel density
on the XY plane are added in the Y axial direction
30   such that a two dimensional image which comprises
pixel density on the X axis is formed. That is,
assuming that the size of the slice image in the Y
axial direction is YSIZE, the projection image $d_1(x,$
z) of the diagnostic images in the Z axial direction
35   is calculated by adding values in the Y axial
direction as shown in the following equation (1).

$$d_1(x, z) = (\sum_{y=0}^{YSIZE} f_z(x, y))/YSIZE \quad ...(1)$$

Then, an almost seamless image sequence is
generated from the discrete projected diagnostic
image sequence by using a leaner interpolation
method or a three-dimensional interpolation method
5   such that the projection image of the diagnostic
images comprising pixel density is generated on the
XZ plane. According to this processing, when
computer processing is used, a completely continuous
function can not be dealt with. Therefore, almost
10 seamless images which are spaced at 1 mm intervals
are generated from images spaced at Z axial
direction (body axis direction) intervals of cm
order. That is, when generating the projection
image from the added image sequence, the Z axial
15 direction is interpolated by the leaner
interpolation method or the three-dimensional
interpolation method. Concerning the interpolation
methods, the leaner interpolation method is better
from the point of view of processing speed. When
20 performing interpolation by the three-dimensional
interpolation method, the following equations (2)
and (3) are used.

$$d(x_0, z_0) \equiv \Sigma_k \Sigma_l d(x_k, z_l) \, c(x_k-x_0) \, c(z_l-z_0) \cdots (2)$$

25
$$C(w) = \begin{cases} 1 - 2|w|^2 + |w|^3 & 0 \le |w| < 1 \\ 4 - 8|w| + 5|w|^2 - |w|^3 & 1 \le |w| < 2 \\ 0 & 2 \le |w| \cdots (3) \end{cases}$$

Next, in step 4 in Fig.5, a projection
30 image of the comparison images is generated in the
same way mentioned above. Fig.7 shows the generation
process.

First, three-dimensional correction images
(comparison images on which resolution matching
35 processing is performed) which comprises pixel
density on the XY plane are added in the Y axial
direction such that a two dimensional correction

image which comprises pixel density on the X axis is generated. That is, assuming that the size of the slice image in the Y axial direction is YSIZE, the projection image sequence $d_1(x, z)$ in the Z axial

5   direction is generated by adding values in the Y axial direction as shown in the following equation (4).

$$d_2(x, z) = (\sum_{y=0}^{YSIZE} g_z(x, y))/YSIZE \quad ...(4)$$

Then, an almost seamless image sequence is

10 generated from the discrete comparison image sequence on the basis of the leaner interpolation method or the three-dimensional interpolation method such that the projection image comprising pixel density on the XZ plane is generated. Since

15 computer processing is used, a completely continuous function can not be dealt with. Therefore, almost seamless images spaced at 1 mm intervals are generated from images spaced at Z axial direction intervals of cm order. That is, when generating the

20 projection image from the added image sequence of the comparison images, interoperation is performed in the Z axial direction by the leaner interpolation method or the three-dimensional interpolation method since the resolution of the X axial direction and

25 the resolution of the Z axial direction are different. Concerning the interpolation methods, the leaner interpolation method is better from the point of view of processing speed. When performing interpolation by the three-dimensional interpolation

30 method, the above-mentioned equations (2) and (3) are used.

The interpolation methods in the Z axial direction are not limited to the leaner interpolation method and the three-dimensional

35 interpolation method. A most neighborhood method can also be used. In addition, the order in which the projection process is performed on the

diagnostics images or the comparison images can be reversed. Interpolation for both of the images is performed after a CT value adding process for both of the images is performed. There is another method

5   for generating the projection images in which slice images at intervals of cm is are interpolated so as to generate slice images at intervals of mm, and then, the adding process is performed on the generated slice images. However, by using the

10   method of the above-mentioned embodiment in which the adding process is performed before interpolation, processing can be performed faster.

     Next, in step 5 in the flowchart, a template for searching the projection image of the

15   comparison images by the projection image of the diagnostics images (template generation processing part 112-6). Fig.8 is a diagram for explaining template pattern matching when using the projection image in the Y axial direction.

20   In the example shown in Fig.8, a rectangular template is generated in the projection image around the area of aortic arch which is in the upper part of lung. That is, the template covers the area of 25%~50% from the top end of the image

25   in the Z axial direction and 10%~90% from the left end of the image in the X axial direction which covers width of lung in the image. Generally, in the projection image of the diagnostic images, the rectangular template is generated as an area which

30   is A%~B% (A, B∈ [0, 100]) from the top end of the object in the Z axial direction and U%~V% (U, V∈ [0, 100]) from the left end of the object in the X axial direction.

     In the case that the object of the

35   diagnostic images is lung, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as

mentioned above, the after-mentioned pattern matching can be performed effectively. Generally, it is desirable that the area of the template is determined such that texture is relatively plainly

5   visible and amount of change of the image due to breathing or the like is small.

Next, pattern matching is performed in step 6. That is, in order to search for an area in the comparison projection image which is the same

10 as the template, pattern matching is performed while shifting the center of the template by several mm from $(50-25)/2=12.5\%$ to $100-12.5=87.5\%$ in the Z axial direction and from $(90-10)/2=40\%$ to $100-40=60\%$ in the X axial direction. Generally,

15 pattern matching is performed while shifting the center of the template from $(B-A)/2\%$ to $100-(B-A)/2\%$ in the Z axial direction and from $(V-U)/2\%$ to $100-(V-U)/2\%$ in the X axial direction (matching processing part 112-7).

20 Finally, in step 7, when the same area as the template is found in the comparison projection image, the shift amount of the comparison projection image in the Z axial direction is measured and the slice position of the comparison image sequence is

25 corrected by the shift amount (slice position correction processing part 112-8). Then, in step 8, the diagnostic image and the comparison image in the slice position which has been corrected are displayed on a display of the image comparison

30 system in Fig.3 or the monitor (monitor 15) of the image alignment apparatus in Fig.4 (display processing part 112-9).

After displaying the images on the display, precise position adjustment is available by using

35 the MIDI device such as the pedal, the dial or the slider. That is, each of the positions of the diagnostic images and the comparison images can be

adjusted in the Z axial direction. In addition, after the position is adjusted, both of the slice images can be displayed while synchronizing them. Accordingly, by using a MIDI device for terminal

5 operation in the image comparison, the operation becomes

effective.

In the above-mentioned embodiment, the direction for projection is not limited to the Y

10 axial direction. The X axial direction and any other directions can be used. In addition, the method for adjusting resolution is not limited to scaling the comparison images. There's nothing wrong with using methods such as scaling the

15 diagnostic images or scaling both of the images.
(second embodiment)

Next, the second embodiment of the present invention will be described.

In the following embodiment, concerning

20 chest X ray CT images for lung cancer screening, it is assumed that present images are compared with previous images.

The definitions of the X, Y and Z axes are the same as those shown in Figs.1A and 1B. That is,

25 the X-Y axial direction forms a slice plane of a tomographic of a body such as chest or the like as shown in Fig.1B, and the Z axial direction is a moving direction of a patient bed as shown in Fig.1A. The chest X ray CT images for lung cancer screening

30 are taken by a helical scan CT shown in Fig.1A and information of slice thickness in the Z axial direction is included in a slice image of chest tomographic of X-Y axial directions. The number of images to be taken is from 25 to 30 for one person.

35 Figs.9A and 9B are diagrams showing examples of projection. Fig.9A shows the direction of projection. Fig.9B is a projection image in

which all CT values, which are density value in the image, are added in the X axial direction shown in Fig.9A.

Fig.10 is a schematic diagram showing a
5   configuration example of a chest CT image alignment apparatus according to the embodiment.

A reference number 21 shows a file storing chest tomographic images (diagnostic images) taken this year and a reference number 22 shows a file
10   storing chest tomographic images (comparison images) taken past year. A reference number 23 shows an X axis direction projection image generated by the file 21 and a reference number 24 shows an X axis direction projection image generated by the file 22.
15   In the sequence of CT images stored in the files 21, 22, position shift between slices has occurred due to a difference of subject positions or by deformation of lung due to breathing. A reference number 25 shows a computer system for automatically
20   aligning positions of slice images of the file 21 and position of slice images of the file 22 and displaying slice images at an aligned position.

Fig.11 is a block diagram showing another configuration example of the chest CT image
25   alignment apparatus according to the embodiment.

The chest CT image alignment apparatus includes a terminal apparatus 31 to which a tomographic image reading apparatus 32, a mouse 33, a keyboard 34, and a monitor 35 are connected. The
30   terminal apparatus 31 includes an apparatus control part 311 and a slice image automatic alignment function part 312 for three-dimension tomographic images. The slice image automatic alignment function part 312 for three-dimension tomographic
35   images includes a slice image automatic alignment function and a control part 312-1 for three-dimension tomographic images, a diagnostic image

sequence file 312-12, a comparison image sequence
file 312-13 and a correction image sequence file
312-14 of comparison images. An operating input
part 312-2, a tomographic image external input part

5   312-3, a resolution matching processing part 312-4,
a bed position extracting part 312-5, a shift
correction processing part 316-6, a projection image
generation processing part 312-7, a template
generation processing part 312-8, a matching

10   processing part 312-9, a slice position correction
processing part 312-10, and a display processing
part 312-11 are connected to the slice image
automatic alignment function and control part 312-1
for three-dimension tomographic images. The

15   operating input part 312-2 performs operating input
by connecting the mouse 33 and the keyboard 34. The
tomographic image external input part 312-3 inputs
tomographic images from the tomographic image
reading apparatus 32. The display processing part

20   312-11 displays diagnostic images and comparison
images to the monitor 35.

The tomographic image external input part
312-3 writes data to the diagnostic image sequence
file 312-12. The resolution matching processing

25   part 112-4 reads data from the diagnostic image
sequence file 312-12 and the comparison image
sequence file 312-14. In addition, the resolution
matching processing part 312-4 writes in the
correction image sequence file 312-14 of comparison

30   images. The shift correction processing part 312-6
corrects shift between the diagnostic image and the
comparison image based on the bed position. The
projection image generation processing part 312-7
and the display processing part 312-11 read data

35   from the diagnostic image sequence file 312-12 and
the correction image sequence file 312-14 of
comparison images.

A MIDI device 36 such as a pedal, a dial, and a slider which is mentioned before is connected to the operating input part 312-2.

Fig.12 is a flowchart showing a procedure
5 for measuring position shift and displaying the diagnostic image and the comparison image of the same position by software in the computer shown in Fig.10 or by processing parts of the image alignment apparatus shown in Fig.11 in order to support image
10 comparison. In the flowchart, parenthesized processing parts, which are included in the image alignment apparatus in Fig.11, corresponding to the following procedure are shown. The flowchart will be described.

15 In Fig.12, diagnostic image sequence $f_z(x, y)$ and comparison image sequence $g_z(x, y)$ are input in step 11 and step 12 (tomographic image external input part 312-3).

In step 13, when resolution of the
20 diagnostic images and resolution of the comparison images are different, resolution matching processing is performed for correcting the comparison images such that the resolution of the comparison images agree with that of the diagnostic images by scaling
25 using three-dimension interoperation or leaner interpolation (resolution matching processing part 312-4).

In step 14 and 15, a bed area is extracted from each of the first diagnostic image and the
30 first comparison image (bed position extracting part 312-5). Then, in step 16, Y axis direction shift between the diagnostic image and the comparison images is corrected on the basis of the extracted bed position in which the Y axis direction is
35 perpendicular to the bed position (shift correction processing part 316-6). The bed area is shown in Fig.13A.

In step 17 and step 18, an X axis direction projection image is generated in which the X axis is defined as a direction perpendicular to the corrected Y axis direction (projection image generation processing part 312-7). Projection images are calculated as shown in formulas (5) and (6) in which XSIZE is the size of the slice image in the X axis direction, $d_1(y, z)$ is the X axis direction projection image of the diagnostic images and $d_2(y, z)$ is the X axis direction projection image of the comparison images.

$$d_1(y, z) = (\sum_{x=0}^{XSIZE} f_z(x, y))/XSIZE \ldots (5)$$

$$d_2(y, z) = (\sum_{x=0}^{XSIZE} g_z(x, y))/XSIZE \ldots (6)$$

Since the resolution of the images for screening in the Y axial direction is different from that in the Z axial direction, the projection images are interpolated by the leaner interoperation method or the three-dimensional interpolation method. A most neighborhood method can also be used for interoperation.

Next, in step 19, as shown in Fig.14, a rectangular template is generated in the projection image around the area of the aortic arch which is in the upper part of lung. That is, the template covers the area of 25%～50% from the top end of the image in the Z axial direction and 10%～90% from the left end of the image in the Y axial direction which covers width of lung in the image. In step 20, in order to search for the same area in the comparison projection image as the template, pattern matching is performed while shifting the center of the template by several mm in the Z axial direction and in the Y axial direction. When the same area as the template is found in the comparison projection image, in step 21, the shift amount of the comparison projection image in the Z axial direction

is measured and the slice position of the comparison image sequence is corrected by the shift amount. In step 22, the diagnostic image and the comparison image in the slice position which has been corrected

5   are displayed on a display of the image alignment system in Fig.10 or the monitor (monitor 35) of the image alignment apparatus in Fig.11. After displaying the images on the display, precise position adjustment is available by using the MIDI

10 device such as the pedal, the dial or the slider.

In the second embodiment, similar to the first embodiment, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as mentioned above, the

15 pattern matching can be performed effectively.
(third embodiment)

As shown in Fig.13B, it is also possible to extract the bed area after generating the projection image. In the flowing, an embodiment in

20 which the bed area is extracted after generating the projection image will be described as the third embodiment.

Fig.15 is a block diagram showing an configuration example of the chest CT image

25 alignment apparatus according to the embodiment. The apparatus can be configured as a computer system in the same way as the second embodiment shown in Fig.10.

The chest CT image alignment apparatus

30 includes a terminal apparatus 41 to which a tomographic image reading apparatus 42, a mouse 43, a keyboard 44, and a monitor 45 are connected. The terminal apparatus 41 includes an apparatus control part 411 and a slice image automatic alignment

35 function part 412 for tomographic images. The slice image automatic alignment function part 412 for tomographic images includes a slice image automatic

alignment function and control part 412-1 for
tomographic images, a diagnostic image sequence file
412-12, a comparison image sequence file 412-13 and
correction image sequence file 412-14 of comparison
5   images. An operating input part 412-2, a
tomographic image external input part 412-3, a
resolution matching processing part 412-4, a
projection image generation processing part 412-5, a
bed position extracting part 412-6, a shift
10 correction processing part 412-7, a template
generation processing part 412-8, a matching
processing part 412-9, a slice position correction
processing part 412-10, and a display processing
part 412-11 are connected to the slice image
15 automatic alignment function and control part 412-1
for tomographic images. The operating input part
412-2 performs operating input by connecting the
mouse 43 and the keyboard 44. The tomographic image
external input part 412-3 inputs tomographic images
20 from the tomographic image reading apparatus 42.
The display processing part 412-11 displays
diagnostic images and comparison images to the
monitor 35.

        The tomographic image external input part
25 412-3 writes data to the diagnostic image sequence
file 412-12. The resolution matching processing
part 412-4 reads data from the diagnostic image
sequence file 412-12 and the comparison image
sequence file 412-10. In addition, the resolution
30 matching processing part 412-4 writes in the
correction image sequence file 412-12 of comparison
images. The shift correction processing part 412-7
corrects shift between the diagnostic image and the
comparison image based on the bed position. The
35 projection image generation processing part 412-5
and the display processing part 412-11 read data
from the diagnostic image sequence file 412-12 and

the correction image sequence file 412-14 of
comparison images.

A MIDI device 46 such as a pedal, a dial,
or a slider which is mentioned before is connected
5   to the operating input part 412-2.

Fig.16 is a flowchart showing a procedure
for measuring position shift and displaying the
diagnostic image and the comparison image of the
same position by software in the computer system or
10 by processing parts of the image alignment apparatus
shown in Fig.15 in order to support image comparison.
In the flowchart, parenthesized processing parts,
which are included in the image alignment apparatus
in Fig.15, corresponding to the following procedure
15 are shown. The flowchart will be described.

In Fig.16, diagnostic image sequence $f_z(x, y)$ and comparison image sequence $g_z(x, y)$ are input
in step 31 and step 32 (tomographic image external
input part 412-3).
20 In step 33, when resolution of the
diagnostic images and resolution of the comparison
images are different, resolution matching processing
is performed for correcting the comparison images
such that the resolution of the comparison images
25 agree with that of the diagnostic images by scaling
using three-dimensional interoperation or leaner
interpolation (resolution matching processing part
412-4).

In step 34 and step 35, X axis direction
30 projection images are generated (projection image
generation processing part 412-7). Projection
images are calculated as shown in formulas (7) and
(8) in which XSIZE is the size of the slice image in
the X axis direction, $d_1(y, z)$ is the X axis
35 direction projection image of the diagnostic images
and $d_2(y, z)$ is the X axis direction projection
image of the comparison images.

$$d_1(y, z) = (\sum_{x=0}^{XSIZE} f_z(x, y))/XSIZE \quad \ldots \quad (7)$$

$$d_2(y, z) = (\sum_{x=0}^{XSIZE} g_z(x, y))/XSIZE \quad \ldots \quad (8)$$

Since the resolution of the images for screening in the Y axis direction is different from that in the Z

5 axis direction, the projection images are interpolated by the leaner interoperation method or the three-dimensional interpolation method. A most neighborhood method can also be used for the interoperation method.

10 In step 36 and 37, a bed area is extracted from each of the diagnostic projection image and the comparison projection image (bed position extracting part 412-5). Then, in step 38, Y axis direction shift between the diagnostic image and the

15 comparison images is corrected on the basis of the extracted bed position in which the Y axis direction is defined as a direction perpendicular to the bed position (shift correction processing part 412-6). The bed area is shown in Fig.13B.

20 Next, in step 39, as shown in Fig.14, a rectangular template is generated in the projection image around the area of aortic arch which is in the upper part of lung. That is, the template covers the area of 25%~50% from the top end of the image

25 in the Z axial direction and 10%~90% from the left end of the image in the Y axial direction which covers width of lung in the image. In step 40, in order to search for the same area in the comparison projection image as the template, pattern matching

30 is performed while shifting the center of the template by several mm in the Z axial direction and in the Y axial direction. When the same area as the template is found in the comparison projection image, in step 41, the shift amount of the comparison

35 projection image in the Z axial direction is measured and the slice position of the comparison

image sequence is corrected by the shift amount. In step 42, the diagnostic image and the comparison image in the slice position which has been corrected are displayed on a display of the image alignment

5   system in Fig.10 or the monitor (monitor 45) of the image alignment apparatus in Fig.15. After displaying the images on the display, precise position adjustment is available by using the MIDI such as the pedal, the dial or the slider.

10   In the third embodiment, similar to the first embodiment, by using the template which is 25%~50% from the top end of the projection images in the Z axial direction as mentioned above, the pattern matching can be performed effectively.

15   In the second and third embodiments, other distinctive areas such as a backbone area or a body part contacting the bed area can be used as the reference for correcting Y axis direction shift between the diagnostic image and the comparison

20   image.

In the first, second and third embodiments, when generating the projection image of the diagnostic images or the comparison images, better matching result for the part of bone can be obtained

25   by generating tomographic images in which weight is assigned to bone parts and perform matching by using the images. Specifically, in the above method, image representation density is not set by using density gradation of the actual CT image which is

30   from 0 level to the maximum level gray-scale. Instead, a window level (central density value) and a window width (density width from the central density value) is set by using a mediastinum condition in which bone is highly visible.

35   Similarly, by setting the representation density as the window level and the window width by using lung area condition in which lung texture is highly

visible, better matching result for the part of lung texture can be obtained by generating tomographic images in which weight is assigned to the lung texture. The MIDI device can be used for setting
5   the window level and the window width.

In the first, second and third embodiments, the method for adjusting resolution is not limited to scaling the comparison images. There's nothing wrong with using methods such as scaling the
10   diagnostic images and scaling both of the images.

In the first, second and third embodiments, the chest X ray CT image is described as an example. However, the present invention is applicable to tomographic images of other parts and applicable to
15   tomographic images other than the CT images.

Further, in the first, second and third embodiments, better matching result for a specific part and speedy processing can be realized by generating the projection image in which only an
20   area including the specific part is added in a direction and by performing matching by using the projection image, the specific part including a distinctive part.

Further, in the first, second and third
25   embodiments, when measuring the shift amount between the projection image of the diagnostic images and the projection image of the comparison images, a plurality of templates can be generated from the projection image of the diagnostic images and
30   template matching can be performed by using the templates on the projection image of the comparison images such that the shift amount is measured from a plurality of reference points. Accordingly, shift correction of the slice position becomes more
35   accurate and the better matching result can be obtained. Especially, when comparing the lower part of lung, shift due to breathing can be corrected.

Further, in the embodiments, the procedures shown in Figs.5, 6, 7, 12 and 16 can be realized by a computer as mentioned above. The program for performing the procedure can be stored

5 in a computer-readable medium such as a FD(floppy disk), an MO, a ROM, a memory card, a CD, a DVD, a removable disk or the like. In addition, providing or distributing the medium is possible.

Fig.17 is a block diagram showing a

10 hardware configuration of such a computer. As shown in Fig.17, the computer system includes a CPU 500 by which a process of a program is executed, a memory 501 for temporarily storing data and a program, a hard disk 502 for storing data and a program to be

15 loaded into the memory 501, a display 503 for displaying data, a keyboard 504 for inputting data or commands, a CD-ROM drive 505 and a communication processing unit 506 which enables the computer system to communicate with other computers via a

20 network. The program is installed in the hard disk 502 via the CD-ROM drive 505 then loaded into memory 501 and executed by the CPU 500. According to the computer, the image alignment of the present invention can be performed.

25 As mentioned above, according to the image alignment apparatus of the present invention, slice images of the same body position can be obtained automatically at high speed from two groups of the chest tomographic images of the same person such

30 that the slice images can be presented to a doctor in a short time. In addition, some work for comparing the images beforehand and excessive computer memory area become unnecessary. Further, by using the template which is 25%~50% from the

35 top end of the projection images in the Z axial direction, pattern matching can be performed effectively such that position alignment is

performed quickly.

In the following, a description is provided of the MIDI device which is connected to the operation input part of the image alignment
5   apparatus for control purposes.

Generally, MIDI (Musical Instrument Digital Interface) is a communication control standard for electronic musical instruments which is supported by many personal computers. When a
10 control device such as a dial, a slider or a pedal is necessary for control of a computer, a control device supporting MIDI can be connected relatively easily and the control device can be easily changed and easily increased.
15   Generally, resolution of 128 stages of 0-127 are defined for describing continuous amount change in MIDI signals. Therefore, it does not support control which is finer than the 128 stages. Thus, when control which is finer than the 128
20 stages is necessary in MIDI, a system exclusive message (exclusive information for the system) is used. In this case, although the information is in conformity with the MIDI standard, there is no compatibility. As a result, it becomes difficult to
25 change to another control device which is commercially available.

On the other hand, the MIDI device used for the image alignment apparatus can receive and send signals of higher resolution than 128 stages
30 while keeping compatibility with commercially available MIDI devices. In the following, the method for receiving and sending the signals of higher resolution will be described. Here, a MIDI slider is taken as an example and the case in which
35 256 stage resolution is necessary is taken as an example.

Generally, the control signal of MIDI

device has resolution of 128 stages of 0−127.
Therefore, if it is used as it is, higher resolution
than 128 stages can not be realized. For this
reason, a 256 stage resolution MIDI slider is

5   designed in which two MIDI channels are used and
data is output by assigning alternately to the
channels as shown in Figs.18 and 19.

A MIDI control change signal includes a
first byte (MIDI channel : identifying each

10   instrument), a second byte (control No. : specifying
a type of control medium) and a third byte (control
value : specifying concrete control value).

It is desirable that channels and control
numbers used for realizing high resolution are those

15   which are not mainly used in a normal controller.
However, to simplify the description, the original
MIDI signal uses a channel 1 and a control number A,
and MIDI channel 2 and the same control number A are
used for realizing high resolution.

20   An application in the MIDI signal
receiving side receives position values of the
slider, each of which position value is one of
values obtained by dividing slider change width into
128. In addition, when a value comes from the

25   channel 2, the application is set such that it
interprets the value as $1/256$ higher than a value
of the channel 1.

In Fig.19, "slider position" corresponds
to a value in 256 stages (the range is from 124 to

30   143 for the sake of convenience), "ch" is the
channel and "value" is the value of 128 stages
output from a slider. When using one channel, the
values of 128 stages of the right section are
converted into the value of 256 stages ($62/128 \rightarrow 124$

35   $/256$. When two channels, $1/256$ is added to the
values converted to 256 stages ($62/128 \rightarrow 124/256 + 1$
$/256 = 125/256$) .

As a result, the receiving application can recognize the position of the slider at 256 stage resolution when using the high resolution MIDI slider. In addition, when a normal MIDI slider is
5 connected instead of the high resolution slider, the normal MIDI slider can receive the same information without any modification.

The high resolution slider is a slider which can use higher resolution signal than the
10 conventional slider. Conventionally, one channel and one control number is assigned to a slider and the slider outputs a value from 1 to 128 according to the movement of the slider. On the other hand, necessary channels and control numbers for realizing
15 high resolution are assigned to the high resolution MIDI slider which outputs signals by synthesizing the channels and control numbers according to the method of the present invention. In the present invention, only the value of the slider and the
20 method for assigning the MIDI signal are defined. Hardware and the configuration for realizing the method are not defined.

By assigning control number instead of the channel, the same effect can be obtained. In
25 practical use, an unassigned channel or a unassigned control number should be selected.

In this embodiment, signals are assigned according to the order of MIDI channels to be multiplexed. In addition, the order can be reverse
30 or random or the like as long as both the receiving side and the sending side have been correlated.

In this embodiment, high resolution signals are divided into equal parts for grouping. However, the signals are not necessarily divided
35 uniformly. That is, when only a part needs high resolution, only the part may be divided into smaller parts such that the parts are allocated to a

plurality of channels, control numbers or the combinations.

In addition, it is not necessary to assign the channels, control numbers or the combinations to

5   fixed specific change areas. Instead, they may be overlapped partially as shown in Fig.20. In this example, six control changes for six MIDI channels are used. In the area A, the resolution is five times larger. In the area B, the resolution is the

10   same as normal state. This method is applicable when precise control is necessary in only a portion of the change area.

As mentioned above, the MIDI signal constructing method includes the steps of: providing

15   n different MIDI channels or control numbers or combinations of them for a signal x which has $128 \times n$ stages in which n is a positive integer; assuming the MIDI channels or the control numbers or the combinations as $p=1$, 2, $\cdots n$; dividing the signal x

20   into 128 parts $W(1)(1 ; 0 \leqq 1 \leqq 127)$ in ascending order and assigning p which is equal to $r+1$ $(r ; 0 \leqq r < n)$ to the signal x which is equal to $1 \times n + r$; constructing and sending a MIDI control change message in which a control value is 1 by using a MIDI channel or

25   control number corresponding to p.

By using the MIDI signal constructing method, when a specific MIDI controller which outputs signals according to the present invention is used, signals according to the resolution can be

30   transmitted and received. When a conventional controller is used, the same control as the specific controller can be performed as a whole. Therefore, by using the MIDI device for the image alignment apparatus of the present invention, precise control

35   can be performed.

The present invention is not limited to the specifically disclosed embodiments, and

variations and modifications may be made without
departing from the scope of the invention.

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